

3. The patient's general and local condition must be watched closely and masterful inactivity employed so far as the dressing is concerned. Dressings, unless for some contra-indication, should not be changed for seven days.

Following the active repair, the structures should be splinted in a position of function. This is most important, as the grafts and underlying structures then will be in the optimum position for a full range of motion or, in event of ankylosis, in the most serviceable position. Proper splinting reduces pain, eliminates swelling and accelerates early functional healing.

In reconstruction of the hand, foot or digits there are many plastic procedures that are most useful for:

1. The removal of adhered scars and neuromata.
2. Applications of grafts with fat pads over painful bony protuberances or contracted areas.
3. Total or partial reconstruction of the thumb and fingers.

It is obvious that certain conditions militate against primary closure:

1. If it is not possible to prepare the part prop-

erly and follow the case for a reasonable time.

2. If, in a case of severe multiple body wounds, the digital injuries are of secondary character.

3. If, due to shock and hemorrhage, immediate repair is not possible.

4. If a long period of time has elapsed since the original injury.

In such cases, primary suture should not be done, but all viable tissue should be preserved and an early secondary closure or grafting should be performed.

Emphasis should be placed on all possible conservation of tissue of the hands, feet and digits. Only that which will obviously necrose should be discarded. Wherever possible, even small parts of digits and extremities should be saved. Ruthless amputation is to be avoided, for every digit is important. No part should be sacrificed merely because to save it would present a difficult problem of closure.

The thumbs and index fingers, the great toes, the heads of the fifth metatarsals and the heels are structures of such prime importance to one's physical and economic well-being that every effort to salvage them should be made.

Primary Treatment of Open Wounds of the Hand*

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AMONG the most common wounds which occur in civil and military life are wounds of the hands. Neglect of seemingly trivial wounds often has disastrous consequences. Many people with superficial injuries will not seek medical attention unless complications arise. Immediate gentle cleansing of these wounds with soap and water has been found to be the most effective prophylaxis of wound infection, a principle which should be promoted for home and emergency room first-aid instead of harmful chemical antiseptics.^{7, 11, 14} Beyond this group of superficial common injuries, almost every open wound of the hand constitutes a surgical emergency unsuitable for office or emergency room care. These injuries demand priority for surgical treatment and hospital care at any time of the day or night.

When the injured patient is first seen, the open wound is immediately protected from further contamination with a sterile dry dressing bandaged so as to control bleeding. Accurate diagnostic procedures are instituted, which include x-ray films, examination of the skin for loss of sensation, and specific tests of motion of the intrinsic muscles and each of the digits. The wound is not probed or peeked into in an attempt to see the extent of damage. The most inadequate test is to inquire if the

patient can wiggle the fingers, since remaining supplemental motions are misleading. In late repair of hand injuries it is not unusual to find a divided median nerve sutured to an adjacent divided tendon; such a crippling error must be assessed primarily to failure to think of nerve injury in hand and wrist wounds, and secondarily to a superficial appraisal of loss of skin sensation and intrinsic muscle function, together with a lack of understanding of the surgical anatomy. The ultimate functional result which may be achieved depends largely upon the accuracy of the preoperative diagnosis.

When the patient reaches the hospital operating room, and when diagnostic tests are complete, adequate anesthesia is induced, general anesthesia being preferred to local anesthesia since a successful repair depends on relaxation of the hand and the patient. The surgeon and attendants, properly gowned, and scrubbed, with their noses and mouths covered by masks, may then proceed with the operation, which in most instances is a major surgical procedure.

CLEANSING OF WOUND

A bloodless field is produced by first wrapping the injured hand and forearm with a sterile elastic bandage, rubber or bias cut stockinet, up to within two inches of a blood pressure cuff bandaged on the arm. The bloodless field is maintained by inflating the cuff to 300 mm. of mercury. Each tube of the cuff is doubly clamped with rubber

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sheathed clamps so as to prevent any possibility of slow leakage. The elastic bandage which produced the primary ischemia is then unwound and removed.¹ The preliminary dressing is removed and the wound is again covered with a sterile dressing. Cleansing of the skin around the wound with soap and sterile water is followed by careful, gentle cleansing of the wound itself with cotton or gauze pads, bland soap and sterile water, followed by a final irrigation with warm sterile salt solution.^{11,14} This preparation has proven eminently satisfactory in transforming a contaminated wound into a clean one. The operative field is redraped and if the surgeon and assistant cleansed the wound, a change of gowns and gloves is performed.

The next approach to the wound is a continuation of the process of mechanical cleansing which entails the meticulous excision of devitalized tissue accompanied by irrigation of the wound with warm sterile salt solution. All possible viable tissue is retained, since there is practically no structure of the hand that can be needlessly sacrificed. This procedure requires gentleness and patience, attention being directed to the preservation of intact structures. In order to repair the divided structures in certain small wounds, it may be necessary to enlarge the wound by incisions placed so as to convert the original wound into a zigzag and to make additional appropriate incisions at a distance from the wound. In such cases, median longitudinal incisions are never made in the fingers, nor are flexor creases bisected at right angles in the fingers or palm.¹ Each of the structures determined to have been injured at the time of the preoperative examination is definitely located. The success of primary repair depends on making secure the anatomical approximation of each divided structure so that physiological repair can take place in a closed wound free from contamination and devitalized tissue with a minimum of foreign-body suture material embedded within the wound.

Most divided blood vessels can be identified and ligated with No. 00000 plain catgut before blood is allowed to return into the hand. If the operation is not too prolonged, the blood pressure cuff is not deflated and removed from the arm until after the nerves and tendons are repaired. After removal of the cuff from the arm, which prevents venous stasis, a period of firm pressure, usually for five minutes or until the transient hyperemia subsides, usually controls capillary oozing. Vessels which continue to bleed are ligated. Fascia and skin closure is then effected, usually with Nos. 34 and 36 stainless steel wire.

REPAIR OF TENDONS

End-to-end suture of divided nerves is performed with interrupted No. 000000 or No. 0000000 arterial silk placed through the nerve sheath only. Tantalum foil is never used to surround the site of a nerve repair, since it produces ischemia and excessive fibrosis inhibiting nerve regeneration.²

Flexor tendons are approximated end-to-end, using No. 34 stainless steel wire suture placed "at a distance" with a "pull-out" suture, which pre-

vents muscle action at the tendon juncture. The ends of the wire tendon suture are brought out through the skin and tied over a button with just enough tension on the tendon to approximate the distal and proximal ends. One double right-angle suture of fine arterial silk may be placed through the opposed tendon ends to maintain exact approximation.¹ Where the juncture occurs in a digital sheath, an adequate slit is made in the sheath, or a segment of the sheath may be excised to permit free excursion of the tendon which, during the healing process, becomes thickened at the site of repair. The steel suture is cut off below the button in three weeks and removed by means of a "pull-out" wire. Guarded active motion is first started at this time and gradually more forceful active motion is allowed after another week. Then, active, purposeful, supervised exercises are instituted to restore function.¹⁰

OPENINGS IN TENDON SHEATH

It has been our observation that primary suture of the flexor tendon in a finger distal to the mid-flexor crease gives satisfactory results and, often, complete return of motion if these principles are applied with an atraumatic technique. In the proximal segment, only the profundus tendon can ordinarily be successfully repaired, and it is usually necessary to excise the sublimus tendon from the proximal phalangeal compartment in order to prevent adhesions between the two tendons and to make room for swelling of the tendon juncture during healing. Here again it is necessary to make a sufficient opening in the tendon sheath to accommodate the excursion of the tendon juncture. In the palm, a lumbrical muscle is used, without disturbing its function or continuity, to surround the site of anastomosis of a profundus tendon, thus preventing adhesions to its adjacent sublimus tendon.

In the repair of an extensor tendon on the dorsum of the hand or fingers, a figure-of-eight No. 34 stainless steel wire is placed through the skin and tendon and is withdrawn in three weeks.¹ Protective splinting is maintained for an additional one or two weeks for extensor tendons.

Where immediate repair of divided structures of the hand can be definitely performed, there must be sufficient viable skin to effect a complete wound closure. If skin loss is so great that the wound cannot be closed, a skin graft or pedunculated flap is used to effect wound closure.^{3,4,13} In this type of wound fractures are reduced, tendon repair is performed, and divided nerves may be repaired or identified with a stitch of fine wire. Where primary healing is not anticipated, immediate tendon and nerve repair is usually delayed until complete healing of the wound is accomplished.

After skin closure, the wound is covered with one layer of sterile fine meshed gauze impregnated with a bland emollient. A large amount of sterile fluffed gauze or mechanic's waste is applied in such a way that, with the application of a bias cut stockinet bandage, gentle pressure is distributed evenly to the wound, maintaining the fingers and thumb in the position of maximum function. A

slab of plaster is applied over this dressing to splint the wrist and fingers in a position that relaxes the injured nerves and tendons during the stage of healing.

TREATMENT OF BURNS

Burns are open wounds and primary treatment follows the principles already outlined for other wounds: Gowns, gloves, and masks for the surgeon and attendants; gentle cleansing with soap and water; the application of a fine mesh, sterile, grease gauze dressing, followed by sterile pressure dressings with immobilization in the position of maximum function. All treatment is devised to prevent contamination of the wound, aseptic precautions being followed during the primary surgical treatment and subsequent infrequent dressings.⁵

General measures to combat dehydration in severe burns are instituted on the basis of the findings disclosed by measurements of plasma volume, red cell mass, interstitial fluid volumes, and plasma protein concentrations. Later, as hemodilution takes place, any progressive loss of red cell volume is corrected by whole blood transfusions. Penicillin may hold infection in abeyance until the initial shock phase is passed so that an early excision of debris may be performed.⁸

Dermatome skin grafts are recommended as soon as possible after necrotic areas have been excised in order to obtain early primary healing. Dry dressings and penicillin are recommended for rapid preparation of the burned areas for skin grafting.⁹ This method permits earlier reconstructive work to be performed by the plastic surgeon.

MULTIPLE STRUCTURAL INJURY

Mangled hands require the greatest exercise of restrained, conservative, surgical skill so that no viable structure is ruthlessly amputated during primary surgical treatment. This applies equally well to complex wounds of the thumb and fingers where immediate formal flap amputation might seem expedient. Saving length by debridement of only devitalized tissue is paramount, followed by immediate skin grafting to cover these stumps, thereby securing a closed wound.

Open fractures require the application of all the surgical principles already described plus maintenance of alignment of the fracture with elastic traction applied in such a way that the position of function is preserved.¹⁵ If a great loss of covering tissue has occurred so that the wound cannot be closed, the use of a pedunculated flap or skin graft makes it possible to transform an open wound into a closed wound at the primary operation.

PUNCTURE WOUNDS IN TENDON SHEATH

Puncture wounds over flexor tendons, particularly in the creases of fingers and thumb, are potentially more dangerous than in other parts of the hand.⁶ For these injuries, immediate hospitalization, parenteral penicillin and voluminous moist warmed dressings offer the greatest hope for prevention of the wrecking effect of infection of the serous lined digital tendon sheaths and palmar spaces. One should not be lulled into a state of un-

suspecting security by such treatment. Instead, an active attitude of constant vigilance must be maintained to detect the first sign of tendon sheath infection. If this disastrous thing should develop, immediate appropriate incisions should be made in the finger by a lateral approach to the tendon beneath the digital nerves and blood vessels with slitting of the sheath throughout the extent of its fibrous portion, and in the hand and wrist, incisions are placed so they enter only the infected space and do not bisect flexor creases or divide nerves.¹ Delay in relieving pressure on a swollen tendon always ends in necrosis of the tendon. The infection may be controlled by the treatment, but swelling of the tendon in its constricted surroundings results in aseptic necrosis and freezing of the tendon within its sheath.

Definite evidence collected during the recent war proves that sulfanilamide and other chemicals have no place in the local treatment of open wounds.¹² The War Department has expressed its attitude as follows: "Experience in wound management justifies the abandonment of local use of any chemical agent in a wound for its supposed antiseptic effect in the prevention or treatment of infection. The practice of routine local application of crystalline sulfonamides to wounds as an emergency aid measure and prior to initial wound surgery will be discontinued."¹⁶

Frequently there arise complicated open wounds of the hand which after thorough diagnostic appraisal will necessitate the services of a surgeon who is especially skilled in this work. With our present developments in speedy air transportation and relatively rapid ground transportation, the patient may be transferred to a distant center for definitive primary treatment. The "golden hours" for primary repair of open wounds in selected cases may now be extended up to 24, and in certain instances, even to 36, by the use of large doses of parenteral penicillin every three hours and oral sulfadiazene. If this program is selected, active treatment of shock, primary cleansing of the wound, and the arrest of active bleeding followed by a pressure dressing should be performed under aseptic conditions, in a hospital, before the patient is transported. Nursing care may be necessary during transportation to manage the medication and look after the general welfare of the patient. A prophylactic dose of 3,000 units of Tetanus antitoxin or a dose of Tetanus toxoid should not be overlooked.

If, in the judgment of the consulting surgeon, a late primary repair should not be attempted, no harm will have been done by the temporary treatment, and the opinion of the consultant is valuable from the standpoint of preservation of function.

Discussion by STERLING BUNNELL, M.D.

This paper covers the subject well. One might emphasize the importance in primary treatment of very thorough excision, or debridement, and of covering over all vulnerable parts such as joints, bones, tendons and nerves. This saves much expense and disability as do, also, formal secondary closures as learned in the last war.

Tendons may be primarily repaired in early, clean wounds. This is successful in most parts of the hand and

forearm, but the results from suture of the flexor tendons between the distal palmar and the middle finger creases are poor the world over. This can, however, be successful if several details are observed. One is to slit the pulley so the tendon can swell at its juncture without its ischemic necrosis. The sublimis tendon, whenever severed in this area, will adhere to the profundus if it is not removed. Another is to refrain from suturing with silk as it causes adhesions. Instead, stainless steel wire is used as it is the least irritating. It need be placed in only one of the tendon ends as only one is active, the other being passive. Still another precaution against causing adhesions is to place the suture at a distance, namely, in the tendon in the palm, bringing it out the skin at the distal end of the palm to be fastened to a button. In three weeks the wire is withdrawn leaving no suture to irritate. When all these points are observed, there will be the least chance for adhesions and good results will be obtained.

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Infection of the Hand, with Evolution of Chemotherapy*

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"EVOLUTION" can best be defined as the growth and development in complexity of a subject. As one views the literature on chemotherapy, the word "confusing" should also be added to the definition. In this brief discussion an attempt will be made to present the basic known facts about the two principal chemotherapeutic agents—the sulfonamides and penicillin—and then to discuss "Infections of the Hand" and relate how these chemotherapeutic agents can be used in the treatment of such infections.

The various points on which there is practically general agreement are as follows:

1. The sulfonamides modify the invasive effects of infections due to hemolytic streptococci, pneumococci and meningococci. They increase the "lag" period by inhibiting the growth of organisms. When used locally, it has been shown that they produce more induration in wounds and more hematoma. It has been shown in Meleney's³ series that they do not lower the incidence of infection in wounds nor do they delay the development of infection. It has also been shown that they do not eliminate the infecting organisms. They are least effective when the local conditions such as traumatized tissue and length of time following injury favor infection. It is now agreed that systemic use of the sulfonam-

ides will do everything that local use of them will do without disadvantages such as increased induration and hematomas in the wound.

2. Penicillin is a chemical produced by a mold which is active against staphylococci and gram-positive organisms in general. It apparently has few toxic effects and is effective if the circulation of the blood can reach the focus of infection. It apparently does not permeate serous or endothelial-lined cavities well and is inactivated by gastric juice. It is less effective in the presence of necrotic tissue and also less effective when the infection is due to mixed organisms.

Briefly then, the sulfonamides are bacteriostatic (prevent the spread of infection but not local infection), are most effective against streptococci, and their use is not indicated locally except to prolong the "lag" period. Penicillin, on the other hand, is not toxic, is effective only if the blood stream can reach the focus, and in any present available form is not effective enough by mouth. Both the sulfonamides and penicillin lose some of their effectiveness in the presence of tissue destruction and under conditions where the local changes in the wound favor infection.

Infections in the hand are predominantly due to staphylococci. Grossmark,² in a series of over 100 infections of the hand, found in 36 pulp infections that all were due to staphylococci; of 32 paronychias, 28 were due to staphylococci; in 23 web infections, 14 were due to staphylococci; in nine

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